Jellyfish respiration from biochemistry

Theodore T. Packard[1], Daniel R. Bondyale-Juez[1], Vanesa Romero-Kutzner[1], Mayte Tames-Espinosa[1], Natalia Osma[2], Igor Fernández-Urruzola[2], Ico Martínez[1], and May Gómez[1]

[1]Marine Ecophysiology Group (EOMAR), IU- ECOAQUA. Universidad de Las Palmas de Gran Canaria, Campus Universitario de Tafira. Las Palmas de Gran Canaria. Canary Islands, Spain. [2]Millenium Institute of Oceanography (IMO), University of Concepción, Barrio Universitario s/n, Concepción- Chile.

BACKGROUND

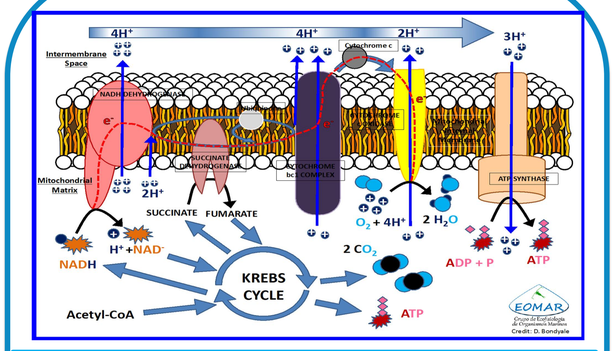


Fig. 1. ETS complexes (4) & ATP-producing enzymatic motor found in <u>all living cells</u>. This is the respiratory Electron Transport (transfer) System. Note proton pumping by 3 complexes and proton re-entry via the motor (ATPase).

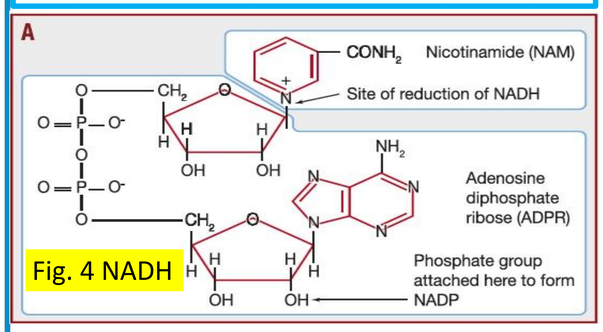
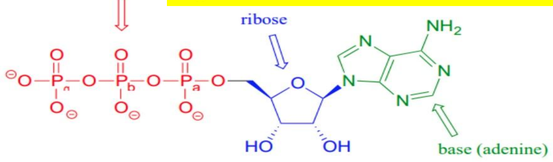


Fig. 4 NADH

triphosphate

Fig.5 ADENOSINE TRIPHOSPHATE



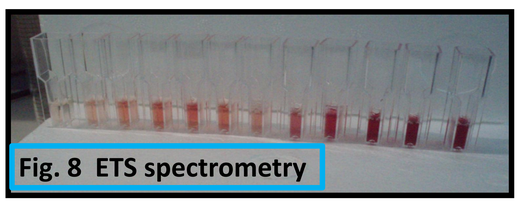


Fig. 8 ETS spectrometry

ACKNOWLEDGMENTS:

PREMISE

1. Jellyfish metabolism needs incorportion (sensu oceanography) in marine ecosystems models.
2. Putting a few jellyfish in bottles and measuring their O_2 use (sensu marine biology) will not provide adequate data.
3. Biochemical sensing, kinetic analysis, and computer modeling must be employed to give requisite data acquisition rates.

BOX 1 Metabolic states of mitochondria (Chance and Williams, 1956; Table V).

State	$[O_2]$	ADP level	Substrate level	Respiration rate	Rate-limiting substance
1	>0	low	low	slow	ADP
2	>0	high	~0	slow	substrate
3	>0	high	high	fast	respiratory chain
4	>0	low	high	slow	ADP
5	0	high	high	0	oxygen

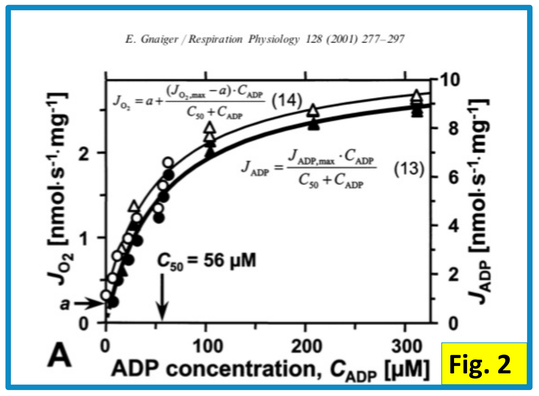


Fig. 2

Fig. 2 Caption: Michaelis-Menten dependence of both respiration (J_{O2}) & ADP phosphorylation (J_{ADP}) on ADP concentration. Note that the K_m of J_{O2} for ADP is 56 µM.

VISION

By extrapolating understanding from biochemical experiments on respiratory control in other organisms we can develop hypotheses about respiratory control in Jellyfish.

VISION BACKGROUND

1. Accordingly, we know from the respiratory ETS (Fig. 1) experiments of Chance and Williams (Box 1), Jacobus et al., and Gnaiger (Figs. 2 & 3) that ADP levels in the vicinity of cytochrome oxidase stimulates respiration (J_{O2}) when O_2, substrate (NADH, Fig. 4) are present. In this situation, ADP (Fig.5), as the index of metabolic demand, drives J_{O2} (Fig. 2 & 3). Analogy: "Demand-side" economics.
2. Pyridine nucleotide availability (mainly NADH) represents the "supply-side" of respiratory control and was explored through modelling (Packard et al., 1996). A theoretical enzyme-kinetic model of Pyridine nucleotide availability in bacteria cultures shifting from nutrient–sufficiency through nutrient-limitation to nutrient-starvation (Fig. 6) successfully predicted J_{O2} in all physiological phases of the cultures (Fig. 7).

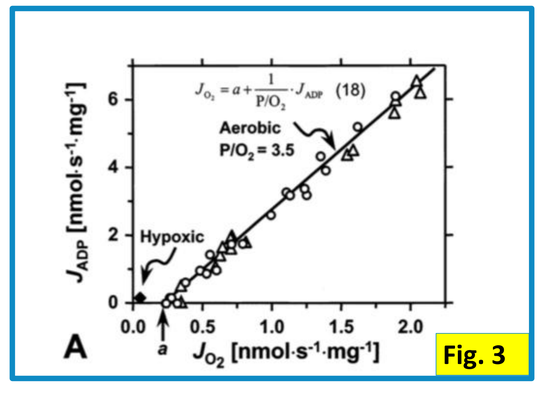


Fig. 3

Fig. 3. Caption: Linear relation between the ADP phosphorylation rate (J_{ADP}) & the respiration rate (J_{O2}). This permits calculation of the J_{ADP} from respiration. Note that J_{ADP} is equivalent to the Heterotrophic Energy Production (Packard et al., 2015).

Fig. 6 Batch culture: Marine bacterium, *Pseudomonas nautica*

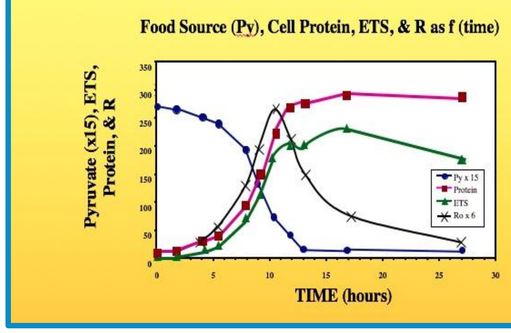


Fig. 6 Caption: Time-course, pyruvate (Py) nourished culture exhausting Py and becoming starved. Note uncoupling between respiration (R) and potential respiration (ETS) as Py approaches zero. Note too, the parallel decline in R and Py after a 5 h lag.

Fig. 7 Respiration from Fig.6. Note parallelism.

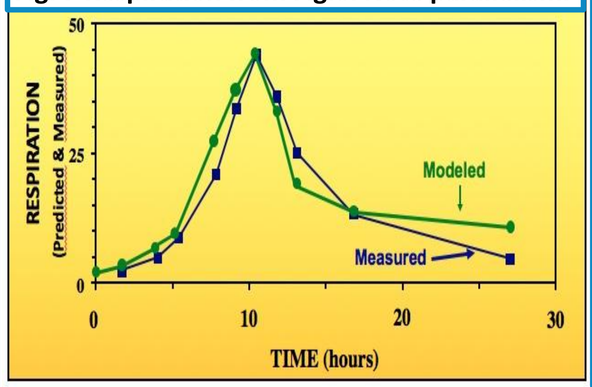


Fig. 7 Caption: First-principles enzyme kinetic respiration model (EKM) based on ETS activity (Fig.8) & data from Fig. 6. Unlike Metabolic-Theory-of-Ecology modeled R, EKM-modeled R matched measured R in both nutrient-sufficient & nutrient-starved cells (Aguiar et al., 2012)!

REFERENCES

Aguiar, B. et al., 2012. JEMBA, 412:1
Chance, B. and Williams, G.R. 1956. Adv. Enzymol. 17:65.
Gainger, E., 2001 Resp. Physiol. 128:277.
Gainger, E. et al, 2019 Resp. Physiol. 128:277.
Jacobus, W.E. et. al. , 1983. J.B.C., 257 (5):2397.
Mitchell, P. 2011. Biochim. Biophys. Acta. 1807:1507.
Packard, T.T. et. al. , 1996. J. Plankton Res. 18 (10):1819.

FUTURE MODELLING

Modelling respiration with an EKM until nutrient limitation becomes extreme is the way to start. Then , the model must include an additional, ADP-dependent term that is activated at zero nutrients. It would mean that ETS activity (Fig. 8), ADP (FIG. 5), NADH (Fig. 4), and their K_ms would need to be measured in seawater.

Hypothesis

Respiration is controled by the ETS respiratory capacity when ETS substrate levels are not limiting, but when starvation commences, respiration is substrate controlled. Later when the externally derrived substrates are exhausted, ADP controls the respiration rate.